Continuation Proposal to the TAMU Turbomachinery Research Consortium

LINEAR-NONLINEAR FORCE COEFFICIENTS FOR SQUEEZE FILM DAMPERS

SQUEEZE FILM DAMPER PERFORMANCE DEGRADATION UNDER A SUDDEN LOSS OF LUBRICANT FLOW

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SIGNIFICANCE

High performance turbomachinery demands high shaft speeds, tighter clearances in the flow passages, and increased tolerance to imbalance. Squeeze Film Dampers (SFDs) are effective means to ameliorate rotor vibration amplitudes and to suppress instability in rotor-bearing systems. A SFD is tailored to a particular rotor-bearing system and satisfies a design damping ratio; if too low, the damper is ineffective, whereas if too large, it locks the system aggravating the system response. At times, SFDs are also employed to control the placement of (rigid body) critical speeds and to displace machine operation into a speed range with effective structural isolation.

THE TEST RIG A multiple-year experimental program funded the construction of a high dynamic load SFD test rig consisting of a rigid journal and an elastically supported bearing cartridge (BC). The rig, shown in Fig. 1, hosts damper configurations operating with large dynamic loads (2.2 kN ≈ 500 lb_f) to induce whirl orbits of increasing amplitude, centered and off-centered. The current configuration is a short length SFD (L/D=0.2) with a nominal clearance of c_A=0.254 μm and film land length L=25.4 mm. In the stationary journal, three 2.5 mm orifices, 120° apart, supply ISO VG 2 lubricant into the squeeze film land.

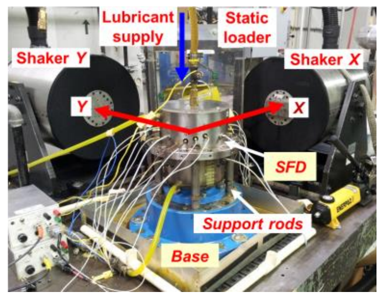

Fig 1. Picture of SFD test rig.

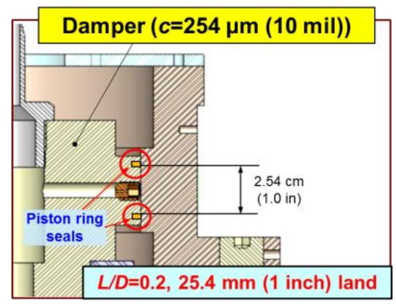

Fig. 2 Cross-section of test damper with piston ring seals.

SUMMARY OF WORK 2015-2016

In 2015, TRC funded work to quantify the force performance of a sealed ends SFD (with piston rings). Tests were conducted with lubricant supplied at pressure P_{in}=0.69 bar and 2.76 bar. TRC report [1] presents force coefficients estimated from circular orbits with increasing amplitude (r/c_A) around three static eccentricity e_s = (0.0, 0.25, 0.50)c_A. As seen in Fig. 3, The direct damping coefficient ($C_{A\text{-}XX}$) increases mildly with orbit radius (r/c_A) and eccentricity (e_s). The SFD inertia coefficient ($M_{A\text{-}XX}$) increases with static eccentricity while decreasing quickly with orbit amplitude.

Fig. 4 compares the damping coefficients obtained from both open ends and sealed ends SFDs versus orbit amplitude (r/c_A). The sealed ends SFD shows, not surprisingly, eleven to thirteen times more damping than the open ends damper. The installed piston ring seals effectively reduce axial leakage and amplify the squeeze film dynamic pressure to produce larger damping forces. Not shown are inertia force coefficients; the sealed ends configuration evidencing eleven times more added mass than that obtained for the open ends SFD.

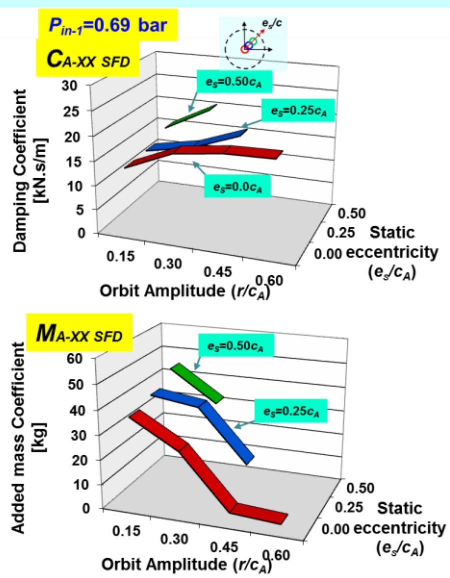

Fig. 3 Sealed ends damper: Damping and inertia force coefficients vs. orbit amplitude (r/c_A) and three static eccentricity e_s/c_A=0.0, 0.25, 0.50. Supply pressure $P_{in\text{-}1}$=0.69 bar.

Fig. 5 depicts the direct damping $(C)_{SFD}$ coefficients for the sealed ends SFD supplied with lubricant at two distinct supply pressures. The coefficients are identified from whirl orbits with amplitude r/=0.15 c_A and an increasing static eccentricity e_s/c_A = 0.0-0.5. The damper operating with a high supply pressure $P_{in\text{-}2}$ = 2.76 bar renders ~26% - 50% larger damping coefficients than those obtained with oil supplied at 0.69 bar. The difference in magnitude increases as the static eccentricity (e_s). Operation with a higher supply pressure delays the onset of oil (vapor) cavitation and prevents air ingestion.

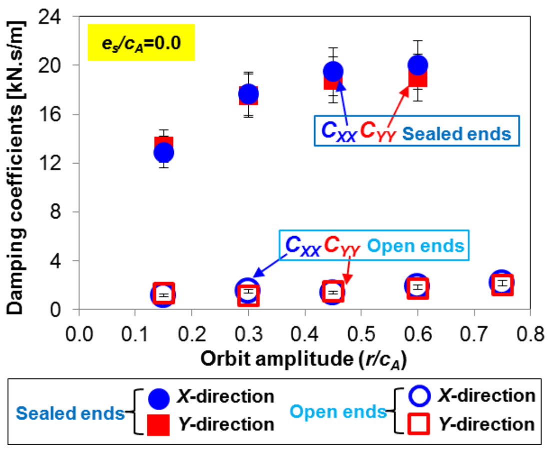

Fig. 4 Sealed ends SFD vs Open ends SFD: direct damping $(C)_{SFD}$ coefficients versus centered orbits with amplitude (r/c_A) at e_s/c_A=0.

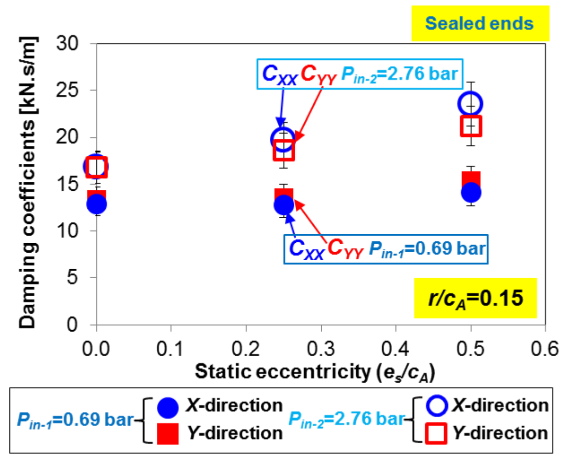

Fig. 5 Sealed ends SFD direct damping $(C)_{SFD}$ coefficients versus static eccentricity (e_s/c_A). Lubricant supply pressure $P_{in\text{-}1}$=0.69 bar and $P_{in\text{-}2}$=2.76 bar.

PROPOSED WORK 2016-2017

SFDs are a means to stabilize aircraft engine rotordynamics due to aerodynamic loads from (gas) sealing elements. Engine qualification requires dampers to operate with a full loss of lubricant over a short period of time, typically 30 s, due to a malfunction or under a sudden 0 *g* maneuver load. Little is known about SFD operation under this stringent condition. In an open ends SFD, once the film starves from lubricant because of a sudden loss of supplied through flow, air ingestion will produce a progressive loss in damping. The worst condition likely occurs when operating with a large whirl amplitude and at high frequency [2,3].

The work in 2016-2017 will quantify damper transient response performance by performing dynamic load tests with the damper at a (largely) off-centered static journal position while the supply of lubricant is suddenly cut. The measurements will evaluate the degradation of damper effectiveness over (a short) time. The proposed work includes:

(a) Machine new journal with film land length and diameter (L/D=0.2) to provide a radial film land clearance of 5 mil.
(b) Characterize the flow conductance of an open ends damper vs. an increasing supply pressure.
(c) With a lubricated system and an open ends SFD, perform dynamic load measurements (fixed amplitude and frequency) while the supply of lubricant is suddenly cut.
(d) Perform analysis (computational predictions) to model test system, compare against measured responses to validate damper flow model.

The proposed research is of interest for SFD applications in aircraft gas turbines and semi-floating ring bearings in turbochargers. Since 1990, TRC sponsors the SFD research program with many practical advances derived from planned experiments and computational analysis.

BUDGET FROM TRC FOR 2016-2017

	Year VI
Support for graduate student (20 h/week) x $ 2,400 x 12 months	$ 28,800
Fringe benefits (2.7%) and medical insurance ($360 /month)	$ 4,995
Supplies for test rig (Lubricant $ 700, Machining a new journal $ 1400)	$ 2,100
Tuition three semesters ($ 363 credit hour x 24 h/year)	$ 9,090
Total Cost:	**$ 44,985**

REFERENCES

[1] Jeung, S-H., and San Andrés, L., 2016,"Experimental Response of an Open Ends SFD Versus a Sealed Ends SFD," **TRC-SFD-01-2016**, Progress Report to the Turbomachinery Research Consortium, May.

[2] Diaz, S., and San Andrés, L., 2001, "A Model for Squeeze Film Dampers Operating With Air Entrainment and Validation With Experiments," ASME J.Tribol., **123**(1), pp. 125–133.

[3] Diaz, S., and San Andrés, L., 2001, ''Air Entrainment versus Lubricant Vaporization in Squeeze Film Dampers,'' ASME J. Eng. Gas Turbines and Power, **123**(4), pp. 871–877.